Finite-Difference Seismic Modeling of Discrete Fractures in a San Juan Basin Gas Reservoir

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As part of a Dept. of Energy sponsored program in fractured gas production, we are conducting numerical modeling of seismic wave propagation in fractured media. The current modeling algorithm is a 2-D, anisotropic, elastic, finite-difference implementation. Fractures are discrete (one grid point wide), vertical, and are described by two parameters, the normal and tangential fracture stiffness, which are converted to anisotropic, elastic constants and placed in an isotropic background.

A five-layer, 2250 m^{2} model with 3 m grid point spacing is used study the effects of fracturing on two scales: long, compliant fractures (i.e. joints) at wide spacing (650 m) and short, stiff fractures at narrower spacing (21 m). The fracture spacing is approximately equal to bed thickness. The fracture stiffness value for the stiff, short fractures was derived from a conceptual model of regularly spaced, infinitely thin openings which are 30 \% of the fracture length. The joints were arbitrarily assigned a stiffness 10 times lower (more compliant). The normal and tangential stiffness were assumed equal (for a model of gas-filled fractures). The layer properties (P- and S-velocity and density) and the model's scale are based on well information from the San Juan basin, focusing on the Mesa Verde unit and its Cliffhouse sandstone member. Surface seismic (including CMP gathers) and VSP geometries, as modeled, werebased on field data acquired in the basin.

The model results (including wavefield time snapshots, and two-component seismograms) show discrete P- and S-wave scattered events from the compliant joints which have large amplitude P-to-S converted phases. These converted waves can be observed in surface seismic acquisition geometry when they are reflected by the horizontal velocity interfaces. In VSP geometry the downgoing fracture-scattered phases can be directly observed. The closely spaced, stiffer fractures generate multiple scattering which is observed as lower amplitude reverberant energy. The range of fracture stiffness used in the modeling appears to give detectable discrete fracture-scattered events based on their relative amplitude as compared to the velocity interface reflections. The fracture scattered events would not be correctly imaged by CMP stacking. Results from initial attempts at fracture-imaging inversion of model data (based on P-to-S scattering), and from models with attenuation added will be presented.